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Reports from the 1990 Professional Seminar

WHAT CAN CHAOS THEORY TELL US ABOUT CONSCIOUSNESS AND BRAIN FUNCTION?

by Glenn Pearce

Glenn Pearce, professor of philosophy, completed his undergraduate work at the College of William and Mary, and graduate studies at Duke University. He taught at the University of Wisconsin and William and Mary prior to joining the faculty of the University of Western Ontario, where he has remained for twenty-three years, and has served as chairman of its philosophy department. His main intellectual interests are cognitive science and metaphysics. He says, "If there were only one question I could ask God, it would be: 'How is the universe put together?' "

The science of chaos, espoused by many of its proponents as the greatest evolutionary leap in scientific understanding since quantum mechanics, reveals a larger mathematical order underlying systems previously considered random. Our ability to apply chaos theory today is largely due to the recent advances in high-speed computer technology. Methods of dynamical analysis developed in the study of complex, chaotic systems may provide a powerful new way of comprehending the behavior of the nervous system under the influence of Hemi-Sync®. In this presentation, Professor Pearce discussed the concepts of chaos theory and suggested lines of investigation which could complement research already under way in the TMI Brainmapping Project.

"Apparently random processes often lead to unexpected order and/or regularity," he said, citing the chaos game as a marvelously simple illustration, "and the same is true of natural processes." The chaos game is played with a conventional die (or any random number generator) and a numbered grid. The game requires only one player—who has about twenty-four hours to devote to randomly casting the die and recording the result of each throw by drawing a dot at the appropriate point on the grid. As the hours tick by, the player sees a definite pattern slowly emerging on the paper. Fortunately for chaos researchers, who may not have the time or inclination for such tedious data gathering, high-speed computers crunch the numbers with ease and speed.

"Conversely," Professor Pearce continued, "apparently random behavior is often governed by very simple equations, subject to 'iterative feedback'." An illustration is provided by the equation (Z2 + C = N) which generates the Mandelbrot set, an extremely complex mathematical object, familiar to the public through its extraordinarily beautiful computer representations. [Zand C are complex numbers chosen at the start; the resulting number, N, is

fed back into the equation as a new value for Z, producing N, etc., the process being repeated ('iterated') indefinitely.] "To a remarkable extent, natural systems—especially biological systems—can be modeled by this technique, and, because of the feedback, they show self-similarity at different scales.

"The traditional contrast between 'orderly' and 'chaotic' behavior," continued Professor Pearce, "is giving way to the idea of different dimensions of complexity . . ." One important measure of this complexity is its fractal dimension. Examples of computer-generated fractal "landscapes" have captured public attention with their eerie resemblance to actual landscapes. Moviegoers have witnessed, if not recognized, fractals in the production of special effects in the film industry. The success of this application of fractal geometry helps to demonstrate chaos theory's fundamental relationship to natural systems.

To explore the application to dynamic systems, we must first draw a map of the system's behavior in "phase space;" a multi-dimensional mathematical space in which each point represents a possible state ("phase") of the system. The actual behavior of the system is then described by a unique trajectory through this space, whose points represent the actual states of the system over time. For a simple example, consider a free-swinging pendulum which eventually comes to rest. The phase space of its behavior would be a trajectory which spirals in to a central zero point. Such spirals come in different sizes, depending on how far and fast the pendulum swings, but they all end at the same point, representing rest. This point is called an "attractor" for the system, since all trajectories lead there. If the pendulum is kept going—by a battery for example—then the phase space trajectory would not be a spiral, but a closed loop. This loop is called a limit cycle attractor, since any initial trajectory would quickly converge on it—so long as the battery power is steady. (Another useful image is a valley surrounded by hills; stones rolling down from any part of the hillside will end up at the bottom, which thus "attracts" them. If you think of hills and valleys of energy, then we can say that the behavior of natural systems is "attracted" by energy valleys and "repelled" by energy hills.)

Complex systems are characterized by "strange" attractors, which are unpredictable because the trajectory never returns to the same point of the limit cycle. More importantly, all known strange attractors are fractals. Thus, the first step in determining what kind of attractors might govern the behavior of a complex system is to discover its fractal dimension. Professor Pearce said that by investigating these attractors ". . . we are slowly but surely approaching the day when we will be able to formulate and test hypotheses about the general principles underlying complex dynamical behavior."

Human brain function is an example of complex dynamical behavior which is the subject of current research in a number of centers. For example, attractors have been constructed for EEG data from subjects doing mental arithmetic and at rest. Some of these were seen in a film preceding Professor Pearce's presentation. His interest is in extending this research to data

from the TMI Brain-mapping Project. He proposes to investigate questions of the following kinds:

- Are there attractors characteristic of specific TMI focus levels?
- Are there attractors characteristic of specific consciousness states, even if not correlated with well-defined TMI frequency patterns?
- Can dynamical analysis begin to provide insight into phenomena seen in the TMI laboratory which, at present, appear to be random events?
- What implications would affirmative answers have for the future development of Hemi-Sync technology and for controlled access to specific states of consciousness?

Professor Pearce reported that he has already consulted with one of the leading researchers in this field—Dr. Paul Rapp of the Medical College of Pennsylvania—whose research team was generous with time and advice. The next step will be to assemble a research group at his university: a brief preliminary discussion with applied mathematicians "shows promise" he says. The most important future step would be to spend extended periods at TMI, working with members of the Brainmapping Project. He hopes his presentation will help to foster that development. In anticipation, he has managed to arrange a year off from teaching, beginning next spring.

(For more information see: James Gleick, *CHAOS: Making a New Science*, Viking Penguin, Inc., 1987; Benoit Mandelbrot, *The Fractal Geometry of Nature*, W.H. Freeman & Co., 1977, 1983.)